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Power System Communications — Interoperability — Guidelines

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Power System Control and Associated Communications Sectional Committee, LITD 10

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Power System Control and Associated Communications Sectional Committee had been approved by the Electrotechnical Division Council.

Indian power sector is growing at an enormous pace. Various grid expansion and interconnection projects are on-going to strengthen the existing transmission infrastructure to build a national grid. The need for interconnecting power networks is in turn driving the need for interconnection of information networks. It is imperative that the power systems today utilize the capabilities that modern information and communication technologies provide. Interoperability among various communicating entities of the power system is crucial for achieving the benefits of a seamless integrated information network.

Electricity or power sector in India is dealing with a number of complex and large issues including demand-supply imbalance, quality of power, financial viability and growth impediments. There is a lot of ground work to be done to address these issues and it would perhaps take at least next ten years or even more to address them. However, there is one area where a lot of progress can be made very rapidly – Standards and Protocols. India can, and must, leverage global best standards for power sector and apply them in Indian market and context.

Interoperability is an important area within standards and protocols and it is addressed in this document. IEEE defines interoperability as the ability of two or more systems or components to exchange information and to use the information that has been exchanged. This definition is about two decades old, long before smart grid term was coined. A slightly recent definition may be appropriate. The measure of ease of integration between two systems or software components to achieve a functional goal. A highly interoperable integration is one that can be easily achieved by the individual who requires the result.

Indian Standard

INTEROPERABILITY IN POWER SYSTEM COMMUNICATIONS — GUIDELINES

1 SCOPE

This standard provides guidelines for achieving interoperability for utilities and applications. The goal is to develop interoperability standards for power sector in India as per the following guidelines which cover the following:

a) The traditional value-chain (generation, transmission and distribution).

b) The newer elements of value-chain (trading, risk-management, renewable generation, ABT (Availability Based Tariff), home/office area networks, system operations (load dispatch centers)).

c) IT (Information Technology), Communication Technology (CT) and Automation or Operational Technologies (AT/OT) and standards based integration between these components/layers.

d) All the layers in the system starting from physical power system infrastructure, the communication network, the system software and application software.

e) Harmonization among standards related to different aspects of the power system.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in Annex A.

3 ABBREVIATIONS

For the purpose of this standard the following abbreviations shall apply:

Description	*Abbreviations*
Availability Based Tariff	ABT
Automated Metering Infrastructure	AMI
Common Information Model	CIM
Distribution Automation	DA
Distributed Energy Resource	DER
Demand Response	DR
Distribution Transformer	DT
Energy Management System	EMS
Enterprise Resource Planning	ERP
Home Automation Network	HAN
Head End System	HES
Meter Data Management System	MDMS
Neighbourhood Area Network	NAN
Phasor Data Concentrator	PDC
Phasor Measurement Unit	PMU
Regional Transmission Operator	RTO
Remote Telemetry Unit	RTU
Unified Modelling Language	UML
Wide Area Network	WAN

4 OVERVIEW OF APPLICABLE STANDARDS

4.1 Areas of Interoperability

The objective of achieving interoperability across the power sector domain is a vast subject and requires standards in different areas. The smart grid requires different components of the power grid to communicate to each other across distinct interfaces. Interoperability is sought to be achieved at the interfaces of each pair of communicating entities. To prioritize the activities it is decided to create a selection of areas that requires interoperable standards at their interfaces. Following is the selection of areas that requires interoperable communication standards. An illustration is provided in Fig. 1.

a) *Intra substation communication* — Communication happening within the boundary of a substation. Includes station bus and process bus communications.

b) *Inter substation communication* — Sending protection, samples, phasor measurements, and process control information between substations in real-time

c) *Field equipment communication* — It represents communications that take place originating from/ destined to devices outside control centres like a data concentrator gathering primary equipment monitoring data.

d) *Substation — Central System Communication* — It includes monitoring and control of substations, pole-top devices, generation plants or distributed energy resources. Exchange of critical and non-critical information to be considered.

e) *Inter central system communication* — It includes exchanging fault information for contingency analysis and emergency operations between Control centres/Data centres. Exchanging metering information from territorial boundaries to initialize state estimation or load distribution applications is another example. Communication may take place between levels of control centres within a utility, or between RTOs.

f) *Central system – DER communication* — This includes communication between utility control centers and Energy Service Providers (ESPs) and Energy Market Participants like real-time pricing negotiations, aggregated customer metering and settlements. May provide data later used for market operations. Communication requirements for control centres to pass metering data to energy market participants also are considered. This environment also encompasses the communications between distributed energy resources and the organizations that must monitor and operate them.

g) *Central system — Enterprise system communication* — The gathering weather data, communicating with regulators, auditors and vendors. May include passing historical data, specifications, network topologies, configuration files, debug traces. Enterprise applications like Billing systems, ERPs are also considered here.

h) *Central system — consumer communication* — This environment encompasses the communications between central system and devices in the consumer premises.

j) *Intra consumer premises communication* — This includes communication within the consumer premises between the smart meter, in home display, smart appliances, etc.

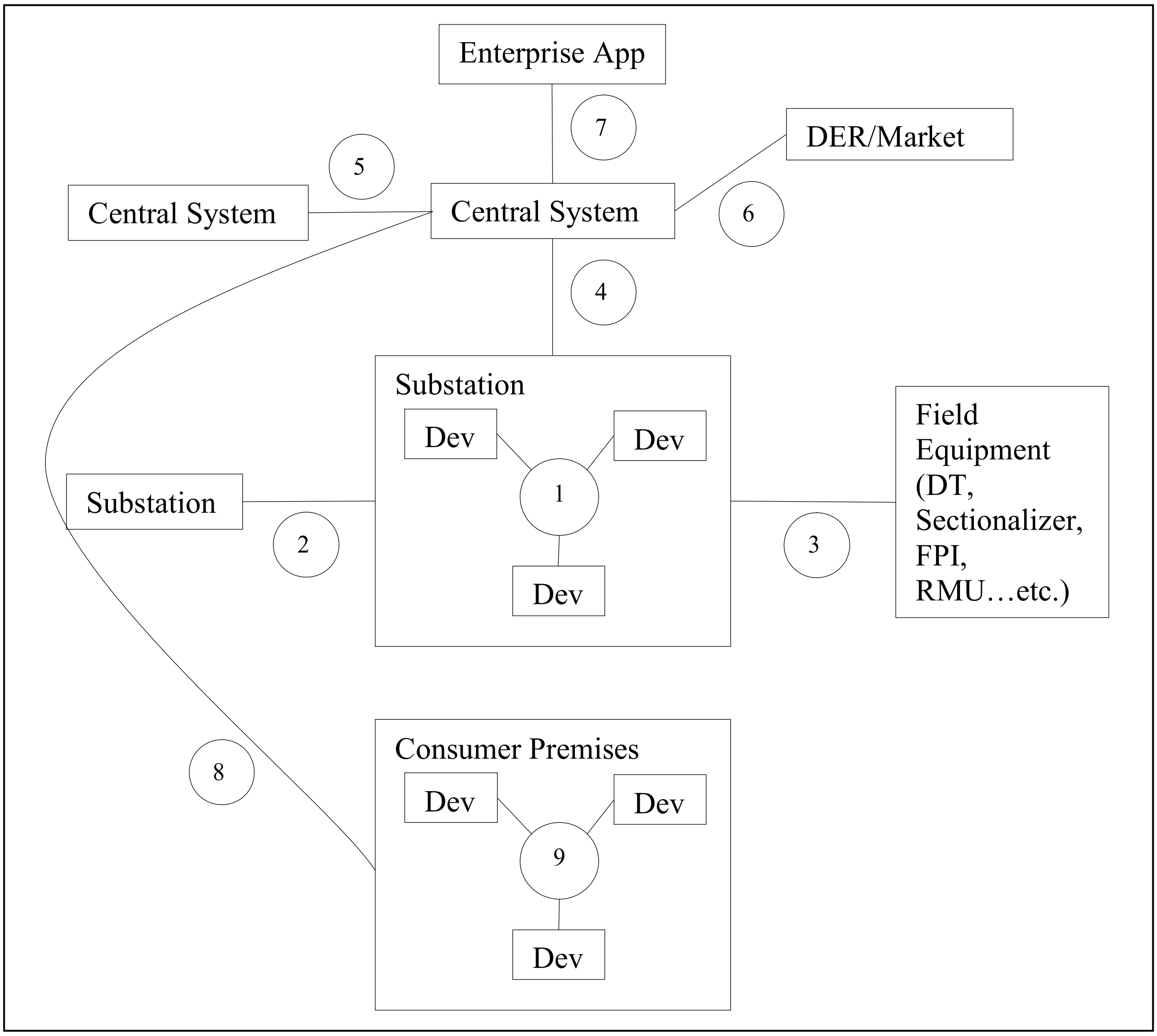


FIG. 1 AREAS OF INTEROPERABILITY AND THEIR INTERFACES

4.2 Guidelines for Selection of Standards

The major principles for the selection of existing standards for the above mentioned areas are the following considering that the standard:

a) is well-established and widely acknowledged,

b) is an established National Standard, where available. In the absence of a suitable National Standard, a stable industry-level standard developed by an open consensus process.

c) has or is expected to have, significant implementations, adoption, and use.

d) is supported by established standard body or users group to ensure that it is regularly revised and improved to meet changing requirements and that there is strategy for continued relevance.

e) is developed and adopted internationally, wherever practical.

f) is integrated and harmonized, or there is a plan to integrate and harmonize it with complementing standards across the utility enterprise through the use of an industry architecture that documents key points of interoperability and interfaces.

g) is openly available under fair, reasonable, and non-discriminatory terms.

h) is associated conformance tests or a strategy for achieving them.

j) has accommodated legacy implementations.

k) allows for additional functionality and innovation through:

   1) *Symmetry* — It facilitates bi-directional flows of energy and information.

   2) *Transparency* — It supports a transparent and auditable chain of transactions.

   3) *Composition* — It facilitates building of complex interfaces from simpler ones.

   4) *Extensibility* — It enables adding new functions or modifying existing ones.

   5) *Loose coupling* — It helps to create a flexible platform that can support valid bilateral and multilateral transactions without elaborate pre-arrangement.

   6) *Layered systems* — It separates functions, with each layer providing services to the above and receiving services from the layer below.

   7) *Shallow integration* — It does not require detailed mutual information to interact with other managed or configured components.

4.3 List of Applicable Standards

List of applicable standards mapped to distinct application domains is given below.

4.3.1 *Domain Areas*

a) *Advanced metering infrastructure* — It consists of the communications hardware and software and associated system and data management software that creates a two-way network between advanced meters and utility business systems, enabling collection and distribution of information to customers and other parties, such as the competitive retail supplier or the utility itself. AMI provides customers real-time (or near real-time) pricing of electricity, and it can help utilities achieve necessary load reductions.

b) *Distribution grid management* — It focuses on maximizing performance of feeders, transformers, and other components of networked distribution systems and integrating with transmission systems and customer operations. As smart grid capabilities, such as AMI and demand response, are developed, and as large numbers of distributed energy resources and plug-in electric vehicles (PEVs) are deployed, the automation of distribution systems becomes increasingly more important to the efficient and reliable operation of the overall power system. The anticipated benefits of distribution grid management include increased reliability, reductions in peak loads, and improved capabilities for managing distributed sources of renewable energy.

c) *Network communications* — The smart grid domains and sub domains shall use a variety of public and private communication networks, both wired and wireless. Given this variety of networking environments, the identification of performance metrics and core operational requirements of different applications, actors and domains in addition to the development, implementation, and maintenance of appropriate security and access controls is critical to the smart grid.

d) *Wide-area situational awareness* — It refers to monitoring and display of power-system components and performance across interconnections and over large geographic areas in near real time. The goals of situational awareness are to understand and ultimately optimize the management of power-network components, behaviour, and performance, as well as to anticipate, prevent, or respond to problems before disruptions can arise.

e) *Demand response, DER and consumer energy efficiency* — It is mechanisms and incentives for utilities, business, industrial, and residential customers to cut energy use during times of peak demand or when power reliability is at risk. Demand response is necessary for optimizing the balance of power supply and demand.

f) *Cyber security* — It encompasses measures to ensure the confidentiality, integrity and availability of the electronic information communication systems and the control systems necessary for the management, operation, and protection of the Smart Grid's energy, information technology, and telecommunications infrastructures.

g) *Electric transportation* — It refers primarily to enabling large-scale integration of plug-in electric vehicles (PEVs).

4.3.2 *Standards Mapped Against Domain and Area of Interoperability*

This section provides a mapping of the relevant standards across two axes, one the application domain being addressed and the other the appropriate area of Interoperability. Various cross-sections of these mappings show multiple candidates for standards that may be applied. Some effort has been spent in ranking these candidates according to suitability but the rankings shown are subject to change, pending a detailed scrutiny of the standards which is beyond the scope of this guidelines document. For the time being, the ranking is indicated by a horizontal sequence of the standards with the left most entries considered most suitable.

4.3.2.1 *Domain – AMI*

Area of Interoperability (Interface Number)	*Standards for AMI*			
Intra substation (1)	Substation Metering – to Substation gateway/HES			
	IEC 62056	IS15959	Modbus	—
Inter substation (2)	—	—	—	—
Field equipment (3)	Pole top DCU, DT Mounted DCU - Upstream			
	IEC 62056	IS15959	—	—
	Pole top DCU, DT Mounted DCU - Downstream			
	Zigbee SEP v1.0/v2.0	IEC 62056 / G3 PLC	IEC 62056 / Prime PLC	IEEE P1901.1
	IEC 62056 / IEC 61334	EN 13757	—	—
Substation – Central System (4)	Substation gateway - upstream			
	IEC 60870-5-104	IEC 62056 / IS 15959	—	—
Inter Central System (5)	Boundary metering data exchange			
	IEC 62056 / IS 15959	—	—	—
Central System – DER (6)	Energy market communications			
	IEC/TR 62325	—	—	—
Central System – Enterprise System (7)	HES – to – MDMS/Billing/ERP, etc			
	IEC 61968 / IEC 61970	Generic Webservices	IEC 62056	—
Central System – Consumer (8)	HES – Meter/Smart home gateway			
	IEC 62056	IS 15959	—	—
Intra Consumer Premise (9)	HAN communications			
	Zigbee SEP v1.0/v2.0	IEC 62056 / G3 PLC / Prime PLC	IEC 62056 / RS232 / Home LAN	IEEE P1901.1
Area-Independent Standards	Security			
	IEC 62351	—	—	—
	Electricity meter specific standards			
	SG-AMI 1-2009	IS 13779	IS 14697	—

4.3.2.2 *Domain – Distribution Grid Management*

Area of Interoperability (Interface Number)	*Standards for Distribution Grid Management*			
Intra substation (1)	Substation process bus			
	IEC 61850-9-2	—	—	—
	Substation station bus			
	IEC 61850	IEC 60870-5-103	Modbus	IEEE 1379-2000
	Disturbance data – Oscillography files			
	IEEE C37.111 - 1999	—	—	—
Inter substation (2)	Synchronized (Special) protection schemes			
	IEC-61850-90-5	IEC-61850	IEC-60870-5-104 / IEC-60870-5-103	Modbus / DNP3
Field equipment (3)	Field DA – Sectionalizer/Totalizer monitoring and control			
	IEC-60870-5-104	Modbus / DNP3	—	Security —
	Fault passage indication / Fault location / FLISR			
	IEC-60870-5-104	Modbus / DNP3	—	—
	Renewable generation			
	IEC 61400-25	—	—	—
Substation – central system (4)	Substation gateway – upstream to control center			
	IEC 60870-5-104	IEC-61850-90-2	DNP3	
Inter central system (5)	Data exchange for scheduling, execution and settlements			
	IEC 60870-6 (ICCP/TASE.2)	IEC-60870-5-104	Modbus	—
Central system – DER (6)	Energy market communications			
	IEC/TR 62325	IEC 61968 / IEC 61970	—	—
Central system – enterprise system (7)	EMS			
	IEC 61968 / IEC 61970	—	—	—
Central system – consumer (8)	—			
	—	—	—	—
Intra consumer premise (9)	—	—	—	—
Area-Independent standards	Security			
	IEC 62351	—	—	—

4.3.2.3 *Domain – Network communications*

Area of Interoperability (Interface Number)	*Standards for Communication Networks*			
Intra substation (1)	Substation process bus			
	Ethernet	RS-485/232/422	—	—
	Substation station bus			
	TCP\IP on Ethernet	RS-485/232/422	—	—
Inter substation (2)	Inter substation communication links			
	TCP\IP-RS232 on PSTN	TCP\IP – RS232 on 2G, 3G, 4G	TCP\IP – RS232 on Optic Fibre	—
Field equipment (3)	Field/Pole-top equipment communication links			
	TCP\IP-RS232 on PSTN	TCP\IP-RS232 on 2G, 3G, 4G	IEEE P1901.1 / G3 PLC	TCP\IP – RS232 on Optic Fibre

Area of Interoperability (Interface Number)	*Standards for Communication Networks*			
Substation – Central System (4)	Substation gateway – Upstream to control center			
	TCP\IP-RS232 on PSTN	TCP\IP-RS232 on 2G, 3G, 4G	TCP\IP – RS232 on Optic Fibre	—
Inter central system (5)	Inter control centers / Data centers			
	TCP\IP – RS232 on Optic fibre	—	—	—
Central system – DER (6)	Market operations / DER integration			
	TCP\IP-RS232 on PSTN	TCP\IP-RS232 on 2G, 3G, 4G	—	—
Central system – Enterprise system (7)	Intra control center / Data center			
	TCP\IP on Ethernet LAN	—	—	—
Central system – Consumer (8)	WAN communications			
	TCP\IP-RS232 on PSTN	TCP\IP-RS232 on 2G, 3G, 4G	—	—
	NAN communications			
	Zigbee SubGHz	Prime PLC / G3 PLC	IEEE P1901.1	—
Intra consumer premise (9)	HAN communications			
	Zigbee 2.4GHz	Prime PLC / G3 PLC	IEEE P1901.1 / IEC 61334 / IEC 12139	RS 232/485 Ethernet LAN
Area-independent standards	General considerations			
	IEC/TS 61085	—	—	—
	Network management			
	SNMP v3	DMTF, CIM, WBEM, ANSI INCITS 438-2008, netconf, STD62, CMIP/CMIS		
	Carrier layers			
	IEEE 802.x	—	—	—

4.3.3.4 *Domain – Wide area situational awareness*

Area of Interoperability (Interface Number)	*Standards for Wide Area Situational Awareness*			
Intra substation (1)	Substation Station bus PMU to Station PDC			
	IEEE C37.118.2	IEC 61850-90-5	—	—
Inter substation (2)	—	—	—	—
Field equipment (3)	PMU to PDC			
	IEEE C37.118.2	IEC 61850-90-5	—	—
Substation – central system (4)	Station PDC to central PDC			
	IEEE C37.118.2	IEC 61850-90-5	—	—
Inter central system (5)	Inter regional center PDCs			
	IEEE C37.118.2	IEC 61850-90-5	—	—
Central system – DER (6)	—	—	—	—
Central system – enterprise system (7)	Central PDC to super PDC			
	IEEE C37.118.2	IEC 61850-90-5	—	—
Central system – consumer (8)	—	—	—	—
Intra consumer premise (9)	—	—	—	—
Area-independent standards	PMU measurement standards			
	IEEE C37.118.1	IEEE 1344	—	—
	—			
	—	—	—	—
	—	—	—	—

4.3.3.5 *Domain – Demand response, DER and consumer energy efficiency*

Area of Interoperability (Interface Number)	*Standards for Demand Response and Consumer Energy Efficiency*			
Intra substation (1)	Substation RTU feeder based demand monitoring			
	IEC 60870-5-104/101	IEC 61850	Modbus	DNP3
Inter substation (2)	—	—	—	—
Field equipment (3)	DT mounted demand monitoring/metering			
	IEC 60870-5-104/101	IEC 62056	—	—
Substation – Central system (4)	Substation RTU feeder based demand monitoring			
	IEC 60870-5-104/101	IEC 61850-90-2	Modbus	DNP3
Inter central system (5)	—	—	—	—
Central system – DER (6)	DER integration to meet demand peak			
	IEC-60870-5-104	—	—	—
Central system – enterprise system (7)	DR aggregation and load management			
	IEC 61968 / IEC 61970	—	—	—
Central system – consumer (8)	—	—	—	—
Intra consumer premise (9)	—	—	—	—
Area-independent standards	Security			
	IEC 62351	—	—	—
	DER and microgrid			
	IEC/TS 62257	IEC 60904	—	—
	—	—	—	—

4.3.3.6 *Domain – Cyber Security*

Area of Interoperability (Interface Number)	*Standards for Cyber Security*			
Intra substation (1)	—	—	—	—
Inter substation (2)	—	—	—	—
Field equipment (3)	—	—	—	—
Substation – central system (4)	—	—	—	—
Inter central system (5)	—	—	—	—
Central system – DER (6)	—	—	—	—
Central system – enterprise system (7)	—	—	—	—
Central system – consumer (8)	—	—	—	—
Intra consumer premise (9)	—	—	—	—
Area-Independent standards	Security			
	IEC 62351			
	NISTIR 7628	ISO 27000	ISA SP99	NERC CIP

4.3.3.7 *Domain – Electric Transportation*

Area of Interoperability (Interface Number)	*Standards for Electric Transportation*			
Intra substation (1)	—	—	—	—
Inter substation (2)	—	—	—	—
Field equipment (3)	Data concentrators / Aggregators communications			
	IEC 62056	IEC 60870-5-104	DNP3	—
Substation – Central system (4)	—	—	—	—
Inter central system (5)	—	—	—	—
Central system – DER (6)	—	—	—	—
Central system – enterprise system (7)	—	—	—	—
Central system – consumer (8)	Charging station to control center			
	IEC 60870-5-104	IEC 62056	—	—
Intra consumer premise (9)	Charging infrastructure			
	IEC 60309	IEC 61851	IEC 61980	SAE J1772
Area-independent standards	Security			
	IEC 62351	—	—	—

NOTE — The list given above are based on literature survey. The domain areas and the existing standards/family identified are based on the study carried out but cannot be considered as exhaustive

5 LEVELS OF INTEROPERABILITY

Interoperability occurs in various levels or layers. These layers span the details of the technology involved to link systems together, to the understanding of the information exchanged, to the business processes and organizational objectives that are represented in business, economic, and regulatory policy. Three broad levels were identified by the working group namely, Communication Technology (CT), Information Technology (IT) and Operation Technology (OT). The scope of these levels are as described below.

5.1 Communication Technology (CT)

This level of interoperability address the technical aspects of communication between the two systems. This covers defining the specifications of basic physical medium of connection, the network addressing and identification mechanism and the protocols for communication.

5.2 Information Technology (IT)

Even though the basic connectivity protocols are satisfied and a certain amount of information is communicated between two systems, the information may not be useful until it is semantically understood on a common basis. This can be achieved by conforming the information being communicated to a standard information model at a higher level of interoperability. As this level the semantics of the content that is communicated is standardised.

5.3 Operation Technology (OT)

At this level, the business context for communication between any two systems needs to be standardized. This defines the high level functions or services that are to be carried out to achieve certain organisational objectives. OT answers why information is to be exchanged, IT answers what information is to be exchanged, CT answers how information is to exchanged as shown in Fig. 2.

5.4 Interoperability and Modularity

The functional requirements are constantly changing in a competitive and expanding power sector in a dynamic regulatory environment. The approach of ensuring layers of interoperability (as described above) would facilitate the utilities to replace individual components of the system without the need for replacing the entire solution from end to end. For example, ensuring interoperability at each layer, would facilitate replacement of communication technology (CT) without any changes in IT and OT layers, or conversely, the OT or IT systems can be replaced individually without the need for changing the CT. The cost implications of not having interoperability are thus enormous.

6 Context Setting Framework for Information Network of Indian Power Sector

In this standard, a model is presented which depicts the logical information network of Indian power sector.

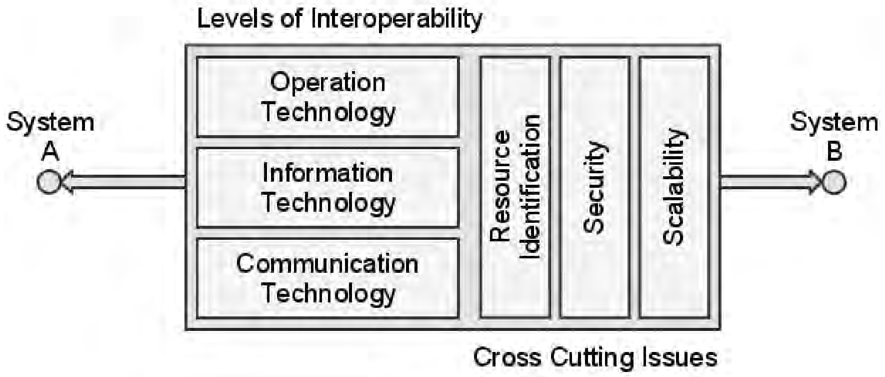


FIG. 2 LEVELS OF INTEROPERABILITY AND CROSS CUTTING ISSUES

The logical information network is essentially a graph with nodes as information sources and sinks, which are interconnected with information branches. Information travels from source nodes to destination nodes over the information links across devices belonging to different systems, organizations, people, information representation formats and communication protocols. For example, National Load Despatch Centre (NLDC) and Regional Load Despatch Centre (RLDC) are two nodes in the network which share information over a communication link. The details of the underlying physical network are not covered in the model. The objective of mapping this information network is to identify all the participants and the types of information that is being exchanged between these participants. It is attempted to make this network model as comprehensive as possible covering all aspects of power system scheduling, operation, control and commercial settlement practices being followed in current Indian scenario.

6.1 Participants of the Information Network

Figure 3 presents the nodes participating the information network. The nodes can be categorized as belonging to different kinds of utilities as described below.

6.1.1 *Generation Utilities*

The generation utilities in India range from regional level to local level. At regional level there are central owned ISGS plants namely NTPC, NHPC and NPC plants. There are private gencos at regional level represented as ultra mega power plants (UMPPs) and independent power producers (IPPS). The gencos at the regional level inject their generation in the regional power pool through the central transmission utilities. Correspondingly at stage level there are state owned gencos, IPPS, MPPs and CPPs who inject their generation into the state power pools VIA the state transmission utilities. At local level all the sources of distributed generation, renewable energy sources are listed.

Every generator has an associated generator substation where the generated power is stepped up and evacuated to the grid. The real-time operational information on all these generators is measured and available at these generator substations VIA its remote terminal units (RTUs). This the substation RTUs form important source nodes in the information network. The RTUs report to the control centres at the corresponding level as shown in Fig. 3.

6.1.2 *Transmission Utilities*

The transmission utilities in India are also hierarchical. Power Grid Corporation of India limited (PGCIL) is the central transmission utility (CTU) at the regional and national level, while there are independent state transmission utilities (STUs) for each state. These CTUs and STUs form sources and sinks of information. The information on availability, maintenance and scheduling of the entire transmission infrastructure is exchanged frequently between the transmission utility with its respective system operator. Similarly, the real time operational data on the entire transmission grid at all levels is obtained from substation RTUs (SS-RTUs). Additionally, phasor measurement units (PMUs) and phasor data concentrators (PDCs) are also being installed at various locations in India, which form a separate path of real-time phasor information reaching the control centres. The commercial settlements in India are carried out on the basis of data retrieved weekly from the special energy meters (SEMs) installed at the interfaces of the constituent power networks. All these information nodes which come under the transmission utilities are depicted in Fig. 3.

6.1.3 *System Operators*

Under the unified load dispatch and communications (ULDC) scheme [9], the entire power system is operated by a hierarchy of control centres with well defined roles and responsibilities assigned to each level of system operation. Control centres form the major part of system operation, participating heavily in the information network.

6.1.4 *Market Operators*

The role of market operators is gradually increasing. Bilateral power traders and power exchanges are involved in carrying out the operations of the power markets. These markets participate in the information network as shown in Fig. 3. Salient features of Indian power market can be summarised as - Energy only, Physical delivery, Voluntary participation, Double sided bidding, Uniform pricing, Day-ahead exchange, Hourly bids, Congestion management by market splitting, Multiple exchanges – Competition amongst exchanges.

6.1.5 *Distributing Utilities*

Following the restructuring of Indian state electricity boards many public as well as private distribution utilities have emerged in India. Distribution utilities (discoms) at the fore front of advancing the role of information technology in their operations are already reaping the benefits of lower losses, faster outage response, higher reliability and customer satisfaction. Thus discoms also need a well connected interoperable network to achieve remote operation capability and automated billing via deploying AMI and AMR.

6.2 Information Networks

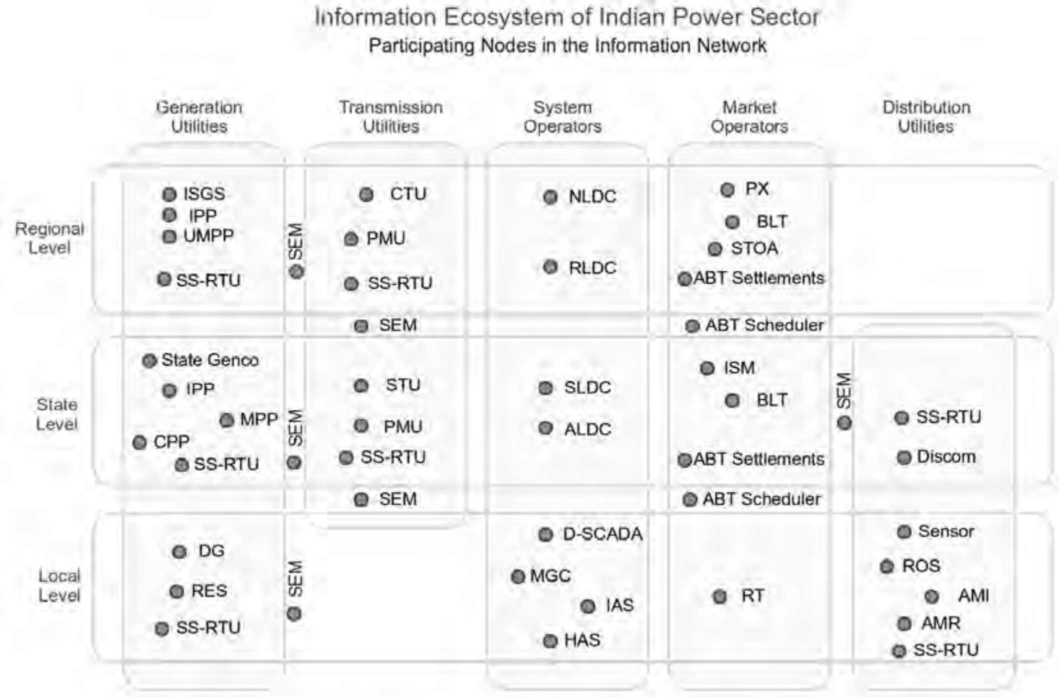
Having identified the nodes in the information network, we move on to connect the nodes and form data flow diagrams. All the data exchanges have been broadly classified into four kinds based in the content being exchanged as defined in following sections.

6.2.1 *Scheduling Data Flow*

The data that is exchanged prior to the event of transfer of electrical energy comprising amount of power to be generated, transmitted and consumed by all the participants of the power network is defined as Scheduling data. The schedule is typically fixed ahead of the day of actual event, referred as (D-1) or before. In India the schedule is ultimately derived out of superposition of various contracts such as , Long Term Open Access (LTOA), Short Term Open Access (STOA), availability based tariff mechanism, power purchase agreements (PPAs), bilateral transactions, power exchange transactions, etc. The nodal agency, at each of the levels (regional, state and local) is responsible for preparation of the schedule. The scheduling data flow network is shown in Fig. 4.

6.2.2 *Operational Data Flow*

The data that is exchanged simultaneously during the event of transfer of electrical energy comprising



Acronym Soup: ISGS – Inter State Generating Station, UMPP – Ultra Mega Power Plants, SS-RTU – substation remote terminal unit, IPP – Independent Power Producer, MPP – Merchant Power Producer, CPP – Captive Power Producer, DG – Distributed generation, RES – Renewable energy sources, CTU Central Transmission Unit, PMU – Phasor measurement unit, SEM Special Energy Meter for intra and interstate Availability based tariff(ABT), NLDC – National load despatch center, RLDC – Regional LDC, SLDC State LDC, ALDC Area LDC, D-SCADA – Distribution supervisory control and data aquisition system, MGC – Micro grid controller, IAS – Industru automation system, HAS – Home automation system, PX – Power Exchange, BLT – Bilateral trader, STOA – Short term open access, ISM – Intra state markets, RT – Retail trader, ROS – Remote operated switch, AMI – Automated metering infrastructure, AMR – Autmated meter reader

FIG. 3 PARTICIPATING NODES IN INFORMATION NETWORK

amount of power actually generated, transmitted and consumed by all the participants of the power network is defined as operational data. The operationally data is typically measured by instruments in substations and transmitted by remote terminal unit (RTU) during the event, and thus is referred as real-time data. The direction of operational is bottom-up flowing to higher levels of hierarchy, while being collected, aggregated and summarised at each level. The operational data flow network is shown in Fig. 5.

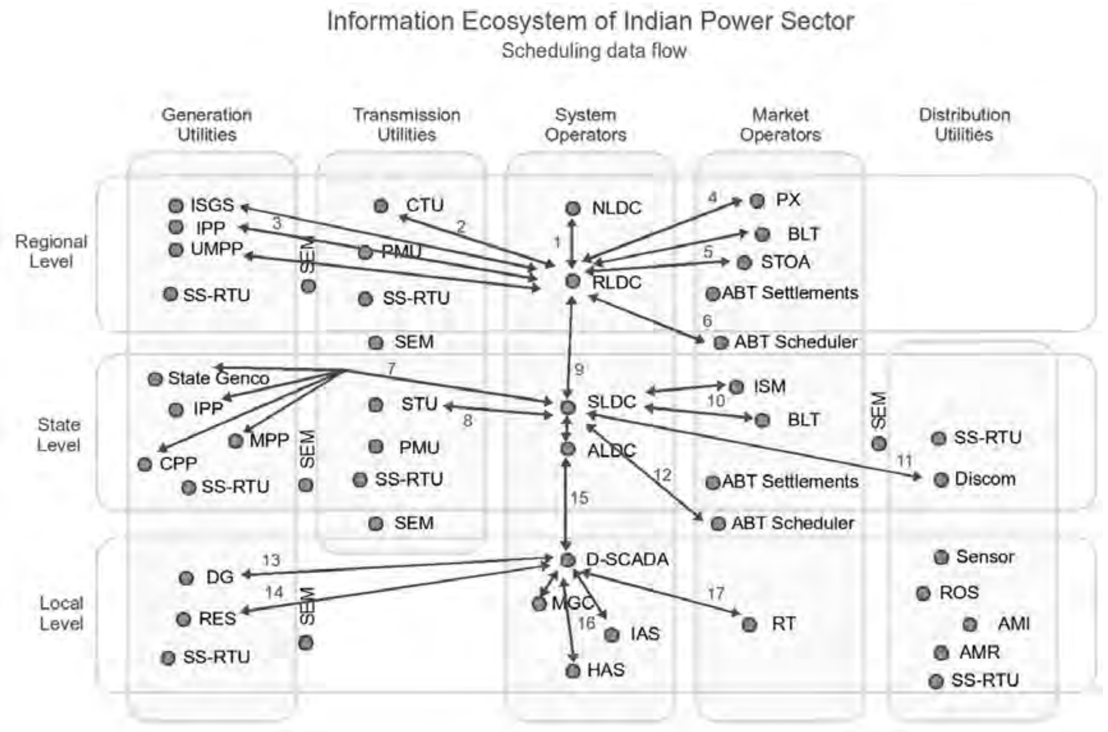


FIG. 4 SCHEDULING DATA FLOW

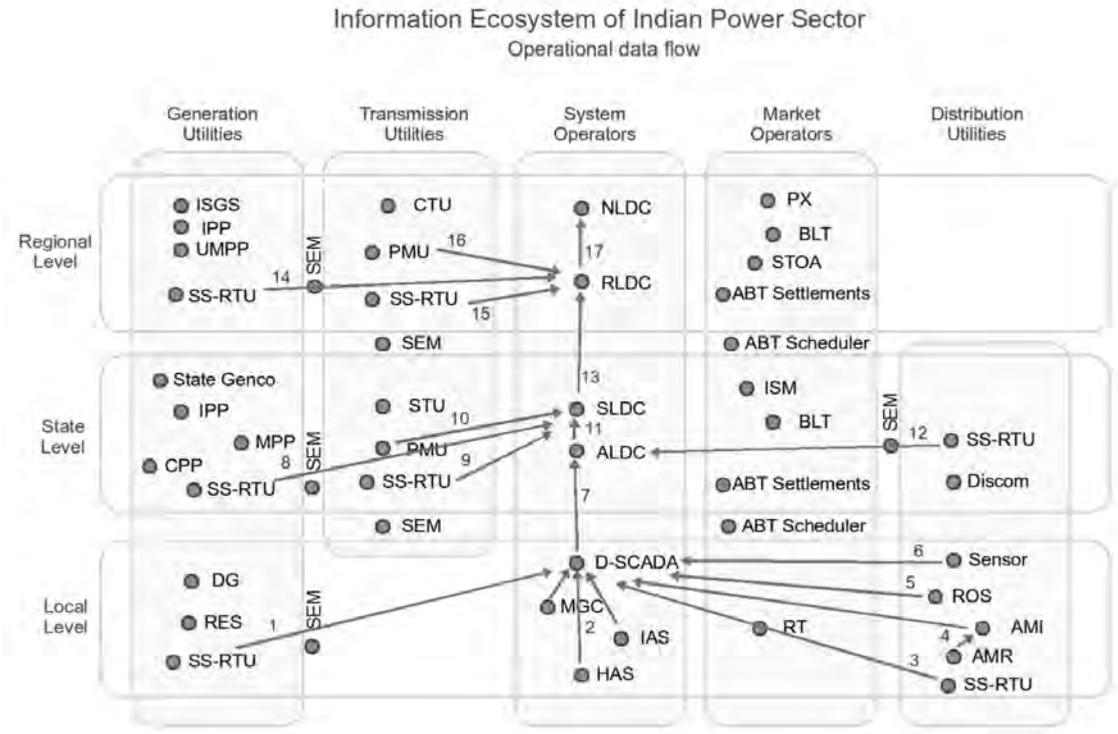


FIG. 5 OPERATIONAL DATA FLOW

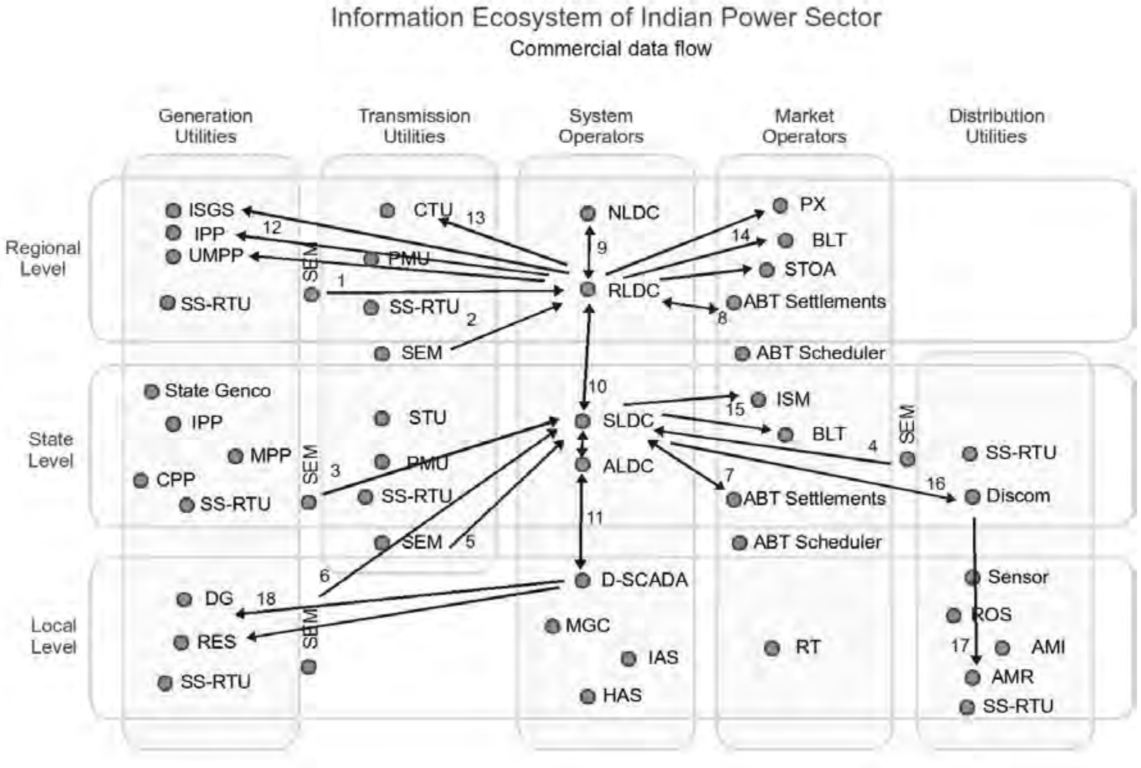


FIG. 6 COMMERCIAL SETTLEMENTS DATA FLOW

6.2.3 *Control Data Flow*

The data that is exchanged as control commands from control centres is defined as control data. The network of control data flow is exactly same as that of operational data flow except that the direction of data flow is reversed. However, it is important to note that the same physical network is typically not used for exchange of control data. Following the decisions made in the control centres the control commands are despatched on phone communication by the operators with the agency who is responsible for carrying out the commands. Thus there is a human intervention in delivery of control operations of the system, which is a hurdle in implementation of closed loop automated control. At distribution system level there are some utilities equipped with capabilities of remote operation of the switches and circuit breakers.

6.2.4 *Commercial Data Flow*

The data that is exchanged after the event of transfer of electrical energy so as to calculate and disseminate the information on commercial settlements to all the participants of the power network is defined as commercial data. The commercial settlement is usually carried out after the day of actual event, referred as (D + 1) or later. The commercial data flow network is shown in Fig. 6.

6.3 Observations

It is seen that at the organisation level, the roles and responsibilities are well defined among various kinds of Indian utilities. This creates a hierarchical network of utilities involved in operating the power network by communicating over the information network. Every link in the communication is backed up with a specific business context as to why such a communication is needed. Following the restructuring of the power sector and under the active contributions from the regulatory agencies at all levels, the public and private utilities are evolving in a dynamic environment. Based on the data flow network in the Figs. 4, 5 and 6, it can be generalized that the information flow is typically assuming a radial tree like structure.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN/INTERNATIONAL STANDARDS

IS No./International Standard	*Title*
13779 : 1999	AC static watthour meters class 1 and class 2
14697 : 1999	AC static transformer operated watt hour and var-hour meters
15959 : 2011	Data exchange for electricity meter reading, tariff and load control — Companion specification
IEC 61968 series	Application integration at electric utilities — System interfaces for distribution management
IEC 61970 series	Energy management system application program interface (EMS-API)
IEC/TS 62351 series	Power systems management and associated information exchange — Data and communications security
IEC 61334 series	Distribution automation using distribution line carrier systems
IEC 62056 series	Electricity metering – Data exchange for meter reading, tariff and load control
SG-AMI 1-2009	NEMA Smart Grid Standards Publication SG-AMI 1-2009 — Requirements for Smart Meter Upgradeability
Zigbee Smart Energy Profile v1.0	ZigBee Smart Energy is a wireless communication standard for interoperable products that monitor, control, inform and automate various processes including the delivery and use of energy and water
EN 13757	Mbus: Communication systems for meters and remote reading of meters
IEC 61850 series	Communication networks and systems in substations
IEEE C37.111-1999	Common Format for Transient Data Exchange (COMTRADE) for Power Systems
IEEE 1379-2000	Recommended Practice for Data Communications Between Remote Terminal Units and Intelligent Electronic Devices in a Substation
Modbus	A generic protocol used to exchange field information from the device to control centre
IEC/TR 62325 series	Framework for energy market communications
IEC/TS 61085 series	General considerations for telecommunication services for electric power systems
IEC 61400-25	Communications for monitoring and control of wind power plants.
Network Management Standards – including Internet based standards	Protocols used for management of network components and devices attached to the network. DMTF, CIM, WBEM, ANSI INCITS 438-2008, SNMP v3, netconf, STD 62, and OSI-based standards including CMIP/CMIS
IEEE P1901	Standard for Broadband over Power Line networks (Broadband communications over Powerline medium access control (MAC) and physical layer (PHY) protocols.)
ISO/IEC 12139 : 2009	Telecommunications and information exchange between systems — Powerline communication (PLC) — High speed PLC medium access control (MAC) and physical layer (PHY)
IEEE 802 Family	This includes standards developed by the IEEE 802 Local Area and Metropolitan Area Network
3GPP Family of Standards – Including 2G, 3G and 4G	2G, 3G, and 4G cellular network protocols for packet delivery. 2G – CSD, HSCSD, GPRS, EDGE, EDGE Evolution 3G – UMTS/FOMA, W-CDMA EUTRAN, HSPA, HSPA+ 4G – LTE Advanced
C37.118.1	Synchrophasor Measurements for Power Systems
C37.118. 2	Synchrophasor Data Transfer for Power Systems
IEC 61850-90-5 : 2012	Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118
IEEE 1344	IEEE Standard for Synchrophasors for Power Systems (Replaced by IEEE C37.118)
IEC 60904 series	Photovoltaic devices
IEC/TS 62257 series	Recommendations for small renewable energy and hybrid systems for rural electrification
ISA SP99	Manufacturing and Control Systems Security

IS No./International Standard	*Title*
ISO/IEC 27000	Information technology — Security techniques — Information security management systems — Overview and vocabulary
NERC CIP	Critical Infrastructure Protection standards
IEC 60309 series	Plugs, socket-outlets and couplers for industrial purposes
IEC 61851 series	Electric vehicle conductive charging system
IEC 61980 series	Electric vehicle inductive charging systems
NISTIR 7628	Guidelines for Cyber Security
ISO/IEC 13335 series	Information technology — Security techniques — Management of information and communications technology security
SAE J1772	Electrical connector between Plug-in Electric Vehicles (PEVs) and Electric Vehicle Supply Equipment (EVSE).

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